EFFECT OF MIG AND TIG WELDING ON HYBRID STRUCTURE USING MODAL ANALYSIS

ILMANFAIQ BIN HAMZAH

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

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EFFECT OF MIG AND TIG WELDING ON HYBRID STRUCTURE USING MODAL ANALYSIS

ILMANFAIQ BIN HAMZAH

Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

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UNIVERSITI MALAYSIA PAHANG

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FACULTY OF MECHANICAL ENGINEERING

I certify that the thesis "Effect of MIG and TIG welding on hybrid structure using modal analysis" is written by Ilmanfaiq Bin Hamzah. I have examined the final copy of this report and in my opinion; it is fully adequate in terms of language standard and report formatting requirement for the award of the degree of Bachelor of Mechanical Engineering. I herewith recommend that it be accepted in partial fulfilment of the requirement for degree of Bachelor of Mechanical Engineering.

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ABSTRACT

Nowadays, joining dissimilar metal by using welding are used in manufacturing industries such as automaker industries. While the common use welding types are Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG). The purpose of joining dissimilar metal is to minimize the cost while maximizes the performance and efficiency of a machine or structure by composing the properties of different metal. Therefore, this project was carried out to study the effect of MIG and TIG welding effect to the hybrid structure using modal analysis. This effect can be determined by investigating dynamic characteristic which was obtained using modal analysis. Aluminium 1100 plate and Stainless steel 304 plate were materials that had been chosen to join using MIG and TIG welding. Experimental modal analysis has been done on both dissimilar plates to obtain the dynamic characteristic. Overall, the comparison result between FEA and EMA show a good consistency error between FEA and EMA and range from 1.16 % to 22.52 %. This study also showed that MIG welding produces structures that has higher natural frequencies compare with the structure that was welded by TIG.

ABSTRAK

Pada masa sekarang, mengimpal dua metal yang berbeza telah digunakan dalam industry pembuatan seperti industry pembuatan kereta. Metal Inert Gas (MIG) dan Tungsten Inert Gas (TIG) adalah dua jenis kimpalan yang biasa digunakan. Tujuan mengimpal dua metal yang berbeza adalah untuk memaksimunkan kebolehan struktur dan mesin sambil meminimunkan kos dengan mengabungkan cirri-ciri yang terdapat pada kedua-dua metal. Oleh itu, projek ini dijalankan bagi mengkaji kesan kimpalan MIG dan TIG pada struktur hybrid menggunakan modal analisis. Kesan kimpalan boleh ditentukan dengan mengkaji dinamik karakteristik yang akan diperoleh dengan menggunakan modal analysis. Aluminium 1100 plat dan Stainless steel 304 telah dipilih untuk dikimpal menggunakan MIG dan TIG. Experimental modal analysis telah dijalankan pada kedua-dua plat untuk memperoleh dinamik karakteristik. Secara kesuluruhannya perbandingan antara FEA and EMA menunjukkan keputusan yang konsisten antara kedua- duanya dengan error dari serendah 1.16 % hingga 22.52 %. Projek ini juga menunjukkan struktur yang dikimpal menggunakan MIG mempuyai natural frequency yang tinggi berbanding dengan struktur yang dikimpal menggunakan TIG.

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LIST OF ABBREVIATIONS

MIG	Metal Inert Gas
TIG	Tungsten Inert Gas
EMA	Experimental modal analysis
FEA	Finite element analysis
FFT	Fast Fourier Transform
CAD	Computer – aided drafting

CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Welding is one of the types of joint that were widely used in the industry. There are many types of welding such as resistance welding, brazing, arc welding and oxyfuel gas welding. Metal Inert Gas (MIG) and Tungsten Inert Gas (TIG) welding are categorized as an arc welding. In order to have a better understanding of the effect of MIG and TIG welding in term of dynamic characteristics of the structure, modal analysis was used. Modal analysis is one of the methods that were used to study the dynamic characteristic of the structure such as natural frequency and mode shape. Other than that, Finite Element Analysis (FEA) also can be used to determine the dynamic characteristic of the structure. The study of the dynamic characteristic of the structure is important so that an incident like the Tacoma Narrows Bridge can be avoided.

1.2 PROBLEM STATEMENT

The used of hybrid structure or dissimilar metals in industrial practice is common nowadays and welding joint is one of the method that was used to join this type of structure. Automakers as an example use dissimilar metal to make a car safer, lighter and more environmentally efficient (Kinsey et al., 2001). The main problem that was faced by the welder is that the welding joint of the dissimilar welding are not strong enough due to the differences of the melting point between the two metals. Many researches were done before to produce a sound joint on the dissimilar metal. The researches that were done only concern on to produce a strong joint on the structure while neglecting the effect on their dynamic characteristic. In order to produce a safer and better structure that will be used by people, the effect welding joins to the dynamic characteristic of the structure also must be understood. This is important so that the structure is safe to be used in any application and field. This research will investigate the effect of the different type of welding on hybrid structure in term of the dynamic characteristic of the structure using modal analysis.

1.3 OBJECTIVES OF STUDY

The objective of this project is to study the dynamic characteristic of hybrid plates that are joined by MIG and TIG welding by using modal analysis and will be validated by results from FEA software.

1.4 SCOPES OF PROJECT

The scopes of the project are stated as below:

a) Selection of available metal and type of joint that will be used in the project
b) Undergo MIG and TIG welding process to join the metals.
c) Modelling the structure by using CAD software and analysis by FEA software.
d) Carry out modal analysis by impact hammer test.
e) Comparison between experimental and theoretical data.
f) Using ODS to determine the dominant mode.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The automakers are trying to produce a car that has a very low consumption by producing lightweight vehicles. Other than that, the automakers also try to maintain their body strength and safety. In order to do that, the automakers usually weld dissimilar metal such as Aluminium and Steel to have both characteristic that was mentioned before. Many researches were done on the dissimilar welding before, deal with the weldable and formability of the weld (Kinsey et al., 2001) and not dynamic characteristic of the structure. To investigate the dynamic characteristic of the structure such as natural frequency and mode shape, modal analysis was used. Modal analysis is used in many fields such as aeronautical, mechanical and automotive to have a better understanding about the structure. This is important to ensure that the structures that have been developed are safe to use by other people. This research was done to study the effect of different welding type such as MIG and TIG welding to the dynamic characteristic of the structure using modal analysis.

2.2 WELDING

Welding can be defined as the process of joining material by heating them to a proper temperature. Nowadays welding is a common method that was used to join two or more pieces of metal to make them act as a single piece. There are many types of welding such as Arc welding, Resistance welding, Brazing, Solid State welding and Oxyfuel gas welding. MIG and TIG welding are categorized in arc welding.

2.2.1 MIG welding

MIG welding was developed in the 1940's and the name was changed to Gas Metal Arc Welding (GMAW) a few years ago and most people are familiar with MIG name comparing to the GMAW. Today MIG is one of the most welding methods, especially in industrial environments. MIG was also popular in robot welding, in which the robot handling the work pieces and welding gun to quicken the manufacturing process. MIG welding uses an arc of electricity to create a short circuit between a continuously fed anode and a cathode. A continuously fed anode is the wire fed gun is used to weld the metal and cathode is the metal that will be welded. The heat that produces by the short circuit along with the inert gas melts the metal and allows the metal to be fused together. When the heat is removed, the metal begins to cool and solidify and forms a new piece of fused metal.

The used of MIG welded aluminium already been used by other researchers but the study are more concern with the properties of the metal after welded. Lefebvre and Sinclair (2005) as example study micromechanical aspects of fatigue in a MIG welded aluminium airframe alloy and not the dynamic characteristics of the structure.

2.2.2 TIG welding

Gas Tungsten Arc Welding (GTAW) or usually known as TIG welding is an arc welding process that uses a non consumable tungsten electrode to produce the weld. The welding atmosphere is protected by an inert shielding gas usually Argon gas or Helium gas. TIG was commonly used to weld thin sections of stainless steel or non-ferrous metal such as aluminium, magnesium and copper alloys. However compare with other welding process, TIG is more complex and difficult to master and slower than most other welding techniques. The effects of a TIG weld to the metal have been studied before but the study is more concern on the microstructures of the metal (Norman et al., 1997). TIG welding was also used to join dissimilar metal in other researches. As example Dong et al. (2011) study the joining of dissimilar metal by using TIG welding.

2.3 DISSIMILAR METAL

Nowadays, joining dissimilar plate is widely used in the manufacturing field. Different kinds of metals feature different properties such as physical, chemical and metallurgical properties. Therefore joining dissimilar metal was done in order to minimize material cost and maximize the performance of the structure. In the present the methods of joining dissimilar metals include fusion welding, pressure welding, and explosion welding. There is also research that was done before to join dissimilar weld using an arc welding (Kinsey et al., 2001).

2.3.1 Aluminium

Aluminium is widely used in the manufacturing of vehicle due to its light properties. Automakers need to produce a car that has lighter weight to ensure the car will has low fuel consumption and meet the standard of Corporate Average Fuel Economy that was imposed by the United State government (Kinsey et al., 2001). Dong et al. (2011) also stated that there has been growing requirement of weld structures made with dissimilar metal between aluminium alloy and steel for weight reduction and energy saving.

2.3.2 Stainless steel

As commonly know, steel has been used in many manufacturing industries due to its high strength properties. Many researches were done before to join dissimilar metal between aluminium alloy and steel. As example Borrisutthekul et al. (2010) in study the feasibility of using TIG weld between aluminium and steel. However steel from a corrosion point of view are poor materials since they rust in the air and corrode in acids. In spite of this there is a group of iron-base alloys, the iron-chromium-nickel alloys known as stainless steel, which do not rust in seawater, are resistant to concentrated acids and which do not scale at temperatures up to 1100°C.

2.4 EXPERIMENTAL MODAL ANALYSIS

Experimental modal analysis or also known as modal testing deals with the determination of natural frequencies, damping ratios, and mode shapes through vibration testing.
In general two basic ideas are involved that is first, when a structure or any system is excited, when damping is small its response exhibits a sharp peak at resonance when the forcing frequency is equal to its natural frequency. Secondly, the phase of the response changes by 180° as the forcing frequency crosses the natural frequency of the structure or machine and the phase will be 90° at resonance. The measurement of vibration usually requires the following hardware such as an exciter, a transducer, a signal conditioning amplifier, and an analyzer (Rao, 2011).

2.5.1 Exciter

Rao (2011) described an exciter is a source of vibration to apply on the structure and it may be an electromagnetic shaker or an impact hammer. The electromagnetic shaker can give large input forces so that the responses can be measured straightforwardly. The output of the shaker also can be adjusted if it is in electromagnetic type. The excitation signal is usually in the form of random type signal or swept sinusoidal. In the swept sinusoidal input, a harmonic force of magnitude F is applied at a number of distinct frequencies over a precise frequency range at concern. At each of the distinct frequency, the structure or the machine is made to reach a steady state before the magnitude and phase of the response are calculated. The mass of the shaker must be taken into consideration if the shaker is attached to the structure. This is important because the mass of the shaker can influence the measured response.

Other than electromagnetic shaker than mention before, another type of exciter that commonly use is impact hammer test. The impact hammer test is a hammer that was built with a force transducer in it and it can be used to hit the structure that is tested.

The impact hammer test is simple, portable, expensive and much faster compare with the shaker but it is often not capable of imparting the sufficient energy to obtain a tolerable response signal in the frequency range of concern.

2.5.2 Transducer

Rao (2011) described transducer is used in modal testing to obtain electrical signal of the structure from its physical motion. The most commonly used and popular transducer is piezoelectric transducer. A piezoelectric transducer can be designed to produce signals that proportional to either force or acceleration. In accelerometer, the piezoelectric operates as a stiff spring that causes the transducer to have a resonant or natural frequency. Usually the maximum measurable frequency of an accelerometer is a fraction of its natural frequency. One of the important things that must be taken into consideration while placing the accelerometer to the structure is, the accelerometer must be placed away from the node shape to ensure that the output signal from the accelerometer can be captured (Chee, 2007) Other than piezoelectric transducer, strain gage can also be used to measure the vibration response of a structure or machine. (Rao, 2011).

2.5.3 Analyzer

The response signal after the conditioning process will be sent to the analyzer for signal processing. A type of signal processing that is commonly used is Fast Fourier Transform (FFT) analyzer. The digital FFT analyzer spectrum analyzer was invented in early 1970's and since that the modal analysis has become more popular and widely used in determining the dynamic characteristic of a structure (Schwarz, 1999).

This analyzer will receive an analogue voltage signal that representing displacement, velocity and acceleration. It will compute the distinct frequency spectra of individual signals as well as cross-spectra between the input and the different output signals. The analyzed signals can be used to find the modal parameters of the structure such as natural frequency, mode shapes and damping ratios in either graphical or numerical.

Figure 2.1 below show the modal testing of a structure that consists of hardware that was mentioned above.

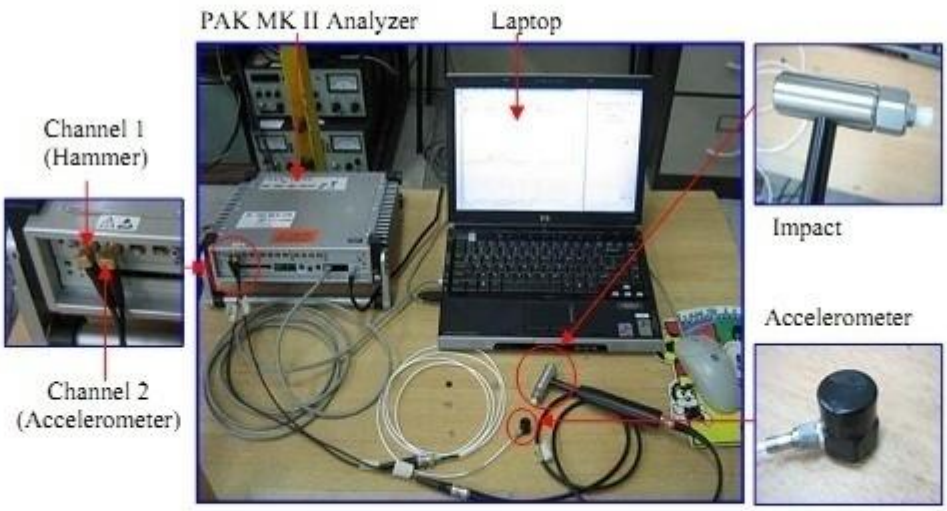


Figure 2.1: Modal Testing of a structure

Source: Chee, 2007

2.5 FINITE ELEMENT ANALYSIS

Logan (2012) describes Finite Element Analysis is a numerical method for solving problems related to engineering and mathematical physics. Areas that usually are using these methods are structural analysis, heat transfer, fluid flow, mass transport and electromagnetic potential. It is generally not possible to obtain analytical mathematical solutions if the problems involve with complicated geometries, loadings and material properties. These analytical solutions generally require the solutions of ordinary or partial differential equations which because of the some condition mention before are cannot be obtained. This is when the numerical method needs to be used to obtain an acceptable solution that approximate with an actual solution. This process model a body by dividing it into an equivalent system of smaller bodies or units (finite elements) interconnected at points common to two or more elements (nodal points) and boundary lines. In the finite element, the problem is solved by formulating the equations for each finite element and combine them to obtain the solution of the whole body (Logan, 2012).   FEA also was used to validate the result that was obtained from the modal analysis. As example Rao (2012) used ANSYS software to validate the result that was obtained from the modal analysis and the result that was obtained shows a good consistency in comparison.

Until the early 1950s, matrix methods and the related finite element method were not readily adjustable for solving complex problems. Even though the finite element method was being used to describe complex structures, there are large numbers of algebraic equations related with the finite element method that made the method are extremely difficult and not practical to use. However with the inventing of computer, we can obtain the solution in a matter of minute. This also gave rise to many FEA software invented that can help to determine the modal parameters of a structure such as ALGOR, ABAQUS, ANSYS and Autodesk.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will explain on how this research was conducted from the start and how the result was obtained. This chapter will also show how the modal analysis was done using several software and test. Other than that, this chapter also will show how the objective that was stated before will be achieved at the end of this project.

3.2 WELDING PROCESS

The materials that were chosen to use as a hybrid structure in this project are stainless steel and aluminium alloy. The material dimension of the metals is shown below in table 3.1.

Table 3.1: Material dimension

Plate	Length (mm)	Width (mm)	Thickness (mm)
Aluminium Alloy (AISI 1100)	150	100	2
Stainless Steel (AISI 304)	150	100	2

Basically there were 4 plates in this project that were analysed in this project. First there is an aluminium plate, second there is stainless steel, third aluminium and stainless steel that was welded by using MIG welding and lastly the aluminium and stainless steel that was welded using TIG welding. The metals that have been selected before, was cut according to the dimension above by using a shearing machine located in the lab. Figure 3.1 shows the shearing machine that was used to cut the metals according to the desired dimension.

Figure 3.1: A shearing machine model TrumaBend V85S

After the metals have been cut by the machine, the plate with the dimension 150mm x 100 mm x 2mm was obtained. The plate was cut according to the dimension mention before because it was the optimum dimension that can be placed on the rig for the MIG welding.

The aluminium and stainless steel plates then were divided into 12 grid points. This grid point was used because the method that was used in the modal testing involving roving Tri axial accelerometer so a point should be determined so that the impact hammer was knocked at a fixed point. The impact hammer was fixed to knock at point 1. Figure 3.2 shows how the metal was divided into grid points.

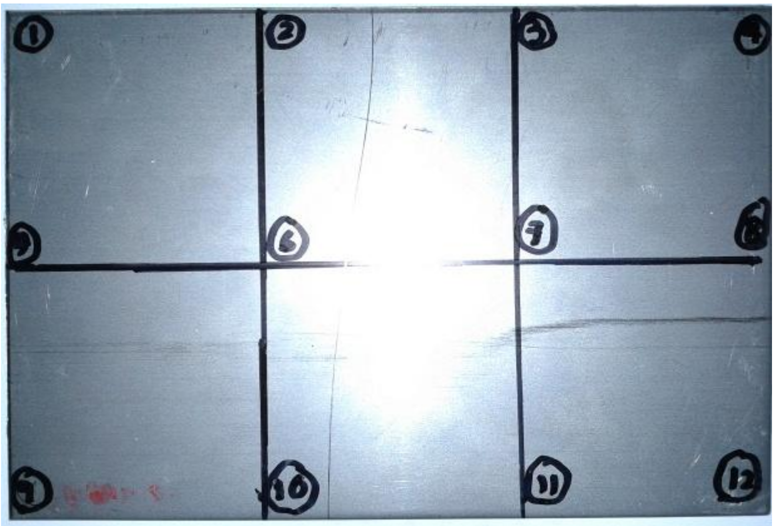


Figure 3.2: Structure that was divided into 12 grid points.

The aluminium plate and stainless steel plate then was welded by using MIG welding and TIG welding machine. Before the welds were done the welding joint was chosen. Butt joint was used in this study and there was no groove was used. The thickness of this structure is only 2mm so there was no groove involved. The MIG welding machine that was used in this study is an automated welding machine located in the welding lab. Figure 3.3 shows how the plate was placed on the rig and figure 3.4 show the MIG welding machine that was used.

Figure 3.3: Structure was placed on the rig before welding.

Figure 3.4: MIG welding machine

The two dissimilar plates then were placed on the rig and the welding was done according to the parameter in table 3.2.

Table 3.2: Welding parameter for MIG weld

Parameters	Description
Voltage (V)	15
Current (A)	80
Weld Speed (mm/s)	1
Filler	Aluminium
Shielding Gas	Argon

Meanwhile the TIG welding joint was done by using a normal TIG welding machine located in the welding lab. Figure 3.5 shows the TIG welding machine that was used.

Figure 3.5: TIG welding machine

The parameters for the TIG welding were shown as below in table 3.3.

Table 3.3: Welding parameters for TIG weld

Parameters	Description
Voltage (V)	Auto
Current (A)	45
Weld Speed (mm/s)	Manual
Filler	Aluminium
Joint	Butt joint
Shielding Gas	Argon

After the welding was done the two structures were divided into 18 grid points. The structure was divided into 18 points so that there was enough space when the accelerometer placed on the structure. Figure 3.6 and 3.7 show how the structures were divided into 18 points.

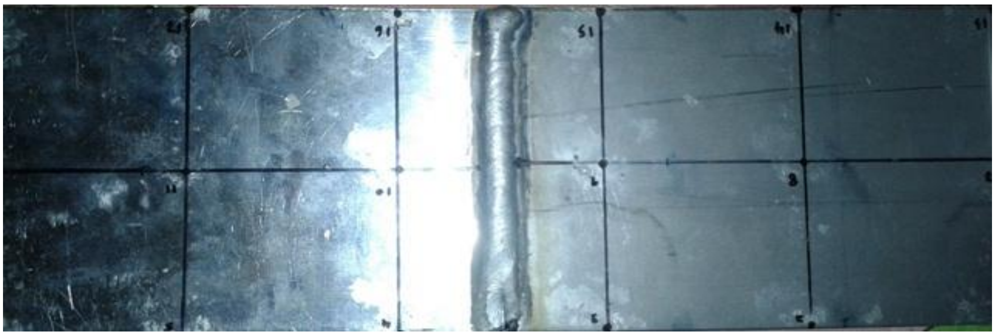


Figure 3.6: MIG weld structure that divided into 18 points.

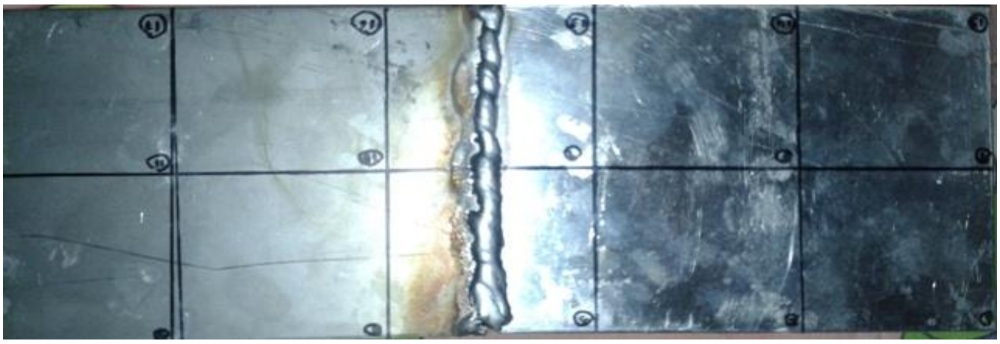


Figure 3.7: TIG weld structure that divided into 18 points.

After the structures were divided into grid points the modal testing was done to find the dynamic characteristic of the structures.

3.3 MODELING

The modelling of the structure in this project will be done by CAD software Solidwork. The modelling of the structure was done according to the actual dimension of the structure and then will be analyses by FEA software to determine the dynamic characteristic of the structure. The CAD software that was used in this project is Solidwork software. The figures below show the modelling that has done by using that software.

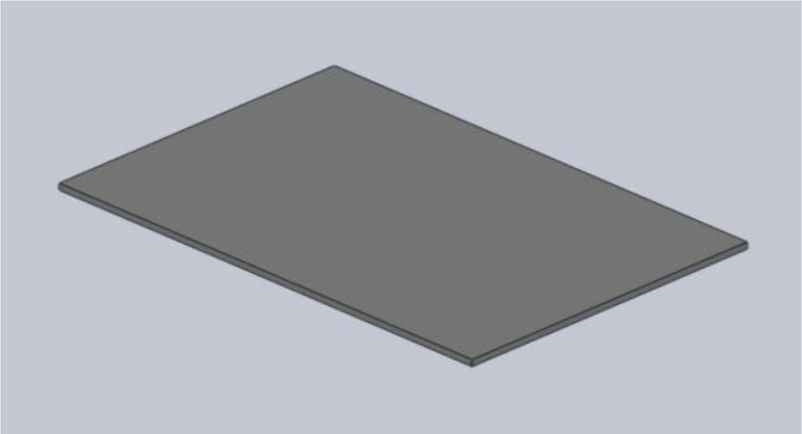


Figure 3.8: Modelling plate

3.4 FINITE ELEMENT METHOD

After the modelling process the data from the Solidwork software will be transferred to ANSYS software for the simulation process. The analysis will be done to aluminium plate, stainless steel plate and the structure that have been joined. The mesh size use is 70%. The analysis done was set to find 4 modes ranges from 1000 Hz to 2000 Hz for the single plate and 300 Hz to 900 Hz for the welded joint. The figure below shows the plates and structure that have been analysed.

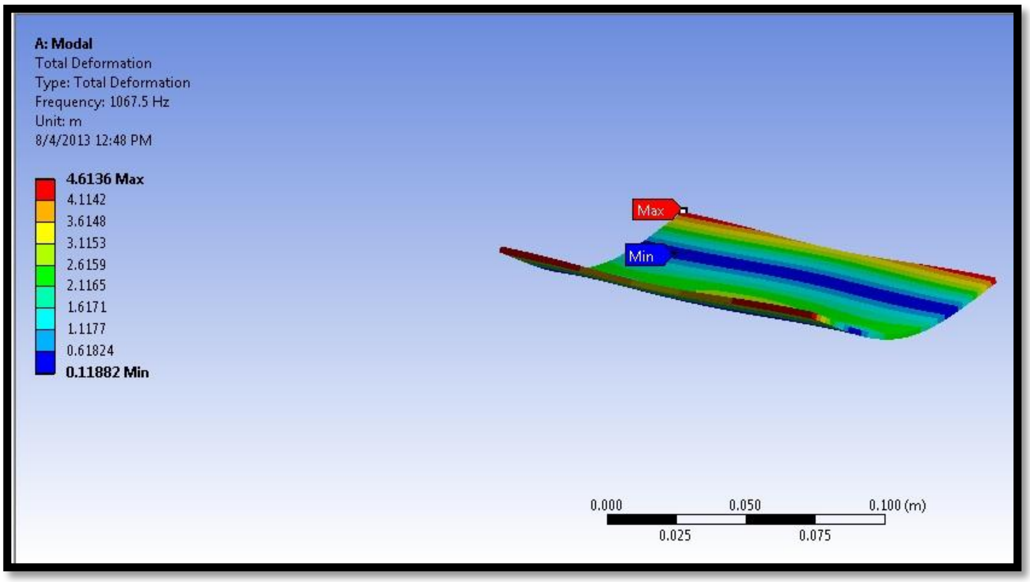


Figure 3.9: Analysis on Stainless Steel plate

3.5 EXPERIMENTAL MODAL ANALYSIS

3.5.1 Impact Hammer test

The hardware that will be used in the impact hammer test consist of a Kistler type 3606 impact hammer with sensitivity of 2.2 MV/g to produce the excitation force on the structure. Other than that a tri axial accelerometer was fixed mounted on the structure near grid 1.

3.5.2 DASYLab

The DASYlab is an analyzer that will convert the analog domain signal into digital frequency domain. From this software the raw data can be obtained before transferring to the MESCOPE software to determine the dynamic characteristic of the structure. The sampling rate use was 2000 Hz with the block size of 4096. Figure 3.10 below show the setup for the modal testing.

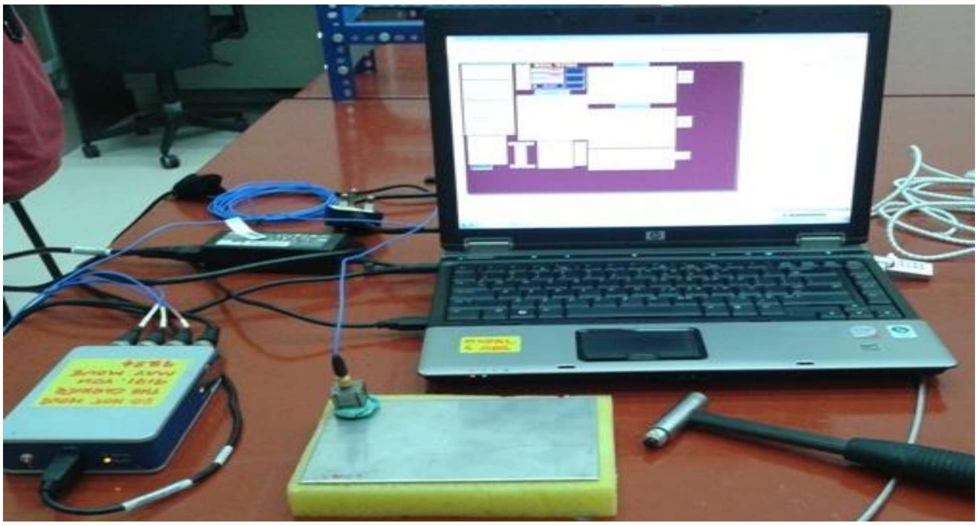


Figure 3.10: Setup for modal testing using DASYLab

3.5.3 ME Scope

The data that is obtained from the DASYLab software can be analyzed by the ME’Scope software. This software will then analyse the data and determine the modes of the structure. The mode shape of the structure such as twisting, bending and others can be determined by this software. Figure 3.11 below show an example of mode shape that was obtained from this software.

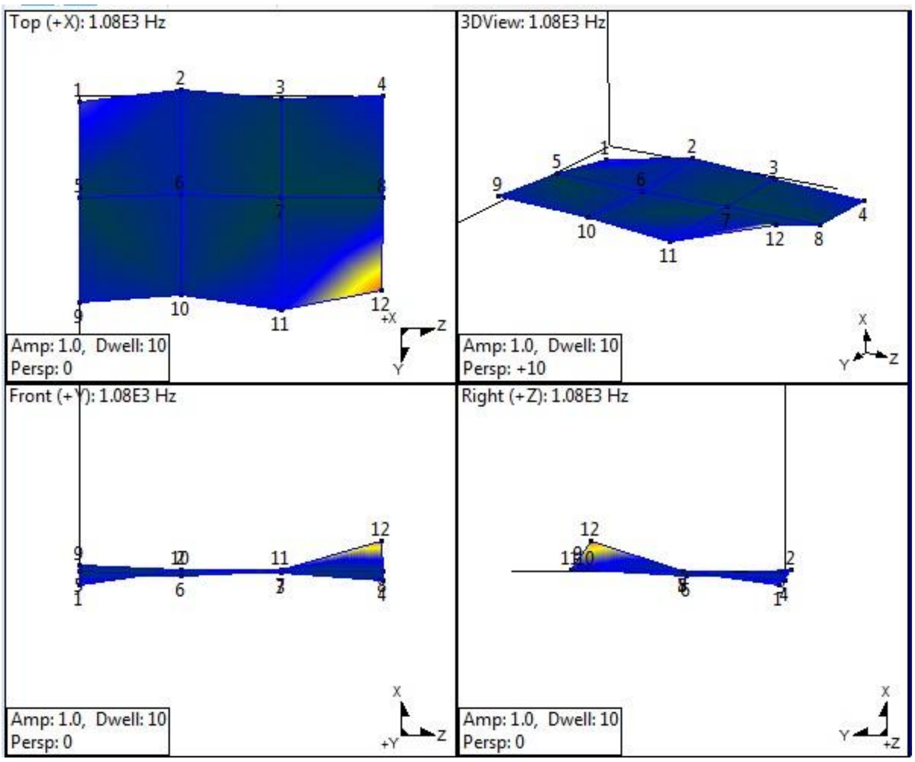


Figure 3.11: Example of Stainless steel plate mode shape.

3.6 COMPARING RESULT

The result that is obtained from the ANSYS software will be compared with the data from the modal testing. With this comparison the error between the FEA and EMA can also be determined. Other than that by using the comparison the modification to the analysis can be done so that the error is relatively small.

3.7 ODS ANALYSIS

The raw data for the Ordinary Deflection Shape (ODS) was obtained from the DASYLab software and the data is calculated by the formula below and analyse by ME'Scope software to determine the mode shape of the structure. Then the mode shape that was calculated will be compared with the mode shape from the ME'Scope software. The hardware was set up as figure 3.12 for the ODS analysis.

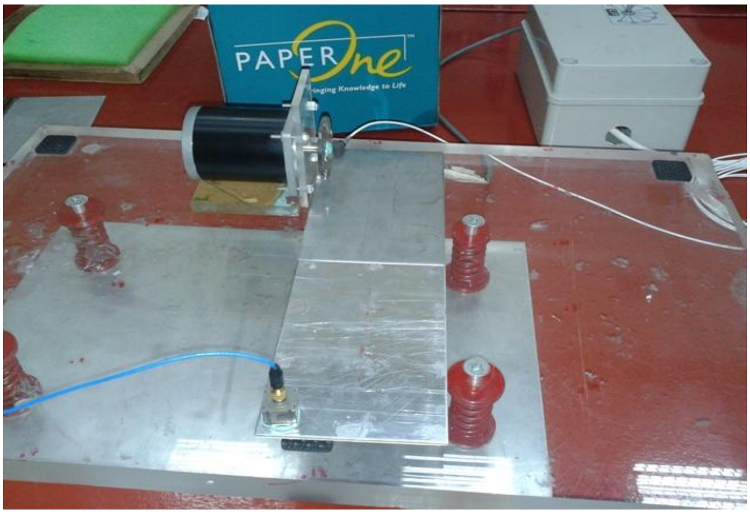


Figure 3.12: Setup for the ODS analysis

The motor was mounted near with points 5 and was running at its maximum speed which is 3217 RPM or equivalent 53.3 HZ. The single axis accelerometer was fixed mounted at point 6. From the DASYLab software the Unit Modal Mass (UMM) was obtained and this raw data transformed into matrix form.

The calculation for the ODS is described in Eq. (3.1) to Eq. (3.4)

$$Br = \frac{1}{\sqrt{(Pr^2 - \omega^2)^2 + (2\sigma r \omega)^2}} \tag{3.1}$$

$$Qpr = \Phi^T \times Q \tag{3.2}$$

$$Xpr = Qpr \times Br \tag{3.3}$$

`

$$Xr = \Phi \times Xpr \tag{3.4}$$

Pr = Response Frequency from UMM

Br = Magnitude of transfer function

Qpr = Force acting on the modal mode

Xr = Response for spatial mode

Xpr = Response in modal

Φ = Matrix

Φ^T = Matrix Transpose

ω = Motor velocity in

σr =Decay rate

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter begin with study of result from both analysis Experimental modal analysis and FEA. The study of the effect MIG and TIG welding on dissimilar plate based on dynamic characteristic. Comparative study both analyses will be validated by result from ODS. Dynamic characteristic like natural frequency and mode shape will be discussed.

4.2 EXPERIMENTAL MODAL ANALYSIS RESULT

The experimental modal analysis was done on 4 plates to determine the dynamic characteristic of the structure such as natural frequency and mode shape. The raw data that was obtain from the DASYLab software was transfer to the MEScope software to obtain the their dynamic characteristic. The result that was generated by the software are as follows.

4.2.1 Aluminium 1100 plate

Table 4.1: Natural frequency Aluminium 1100 plate

Modes	Natural Frequency (Hz)
1	1020
2	1260
3	1550
4	1750

4.2.2 Stainless steel 304 plate

Table 4.2: Natural frequency Stainless steel 304 plate

Modes	Natural Frequency (Hz)
1	1080
2	1310
3	1470
4	1680

Table 4.1 and 4.2 show the result that obtained from the MEScope software for the single plate. The table above shows their natural frequency from mode 1 to mode 4 using experimental modal analysis.

4.2.3 Metal Inert Gas welding

Table 4.3: Natural frequency MIG weld plate

Modes	Natural Frequency (Hz)
1	387
2	567
3	645
4	779

4.2.4 Tungsten Inert Gas welding

Table 4.4: Natural frequency TIG weld plate

Modes	Natural Frequency (Hz)
1	310
2	484
3	612
4	721

Table 4.3 and table 4.4 above, show the natural frequency that was obtain from the plates that was weld by using MIG and TIG welding using experimental modal analysis.

4.3 FINITE ELEMENT ANALYSIS RESULT

The finite element analysis was also done on 4 plates using ANSYS software. The frequency range was set from 1000 Hz to 2000 Hz for single plates and 300Hz to 900 Hz for the welded plates.

4.3.1 Aluminium 1100 plate

Table 4.5: Natural frequency Aluminium 1100 plate

Modes	Natural Frequency (Hz)
1	1089.2
2	1241.1
3	1460.3
4	1842.3

4.3.2 Stainless steel 304 plate

Table 4.6: Natural frequency Stainless steel 304 plate

Modes	Natural Frequency (Hz)
1	1067.5
2	1226.7
3	1430.2
4	1818.8

4.3.3 Metal Inert Gas welding

Table 4.7: Natural frequency MIG weld plate

Modes	Natural Frequency (Hz)
1	330.36
2	439.31
3	617.40
4	736.66

4.3.4 Tungsten Inert Gas welding

Table 4.8: Natural frequency TIG weld plate

Modes	Natural Frequency (Hz)
1	330.36
2	439.31
3	617.40
4	736.66

Table 4.7 and 4.8 show the natural frequency of the MIG and TIG weld that was obtained from FEA software. The result shows the same natural frequency because the weld of MIG and TIG weld can not be defined by using ANSYS software.

4.4 COMPARATIVE STUDY

Table 4.9 and 4.10 show the comparison result between finite element software and modal testing of single aluminium 1100 and stainless steel 340 plates. The figure 4.1 and 4.2 show the graphs plotted to compare the result between the two analyses.

4.4.1 Single plate

Table 4.9: Aluminum 1100 plate

Modes	Modal testing (Hz)	FEA analysis (Hz)	Error (%)
1	1020	1089.2	6.78
2	1260	1241.1	1.50
3	1550	1460.3	5.79
4	1750	1842.3	5.27

Table 4.10: Stainless Steel 304 plate

Modes	Modal testing (Hz)	FEA analysis (Hz)	Error (%)
1	1080	1067.5	1.16
2	1310	1226.7	6.36
3	1470	1430.2	2.71
4	1680	1818.8	8.26

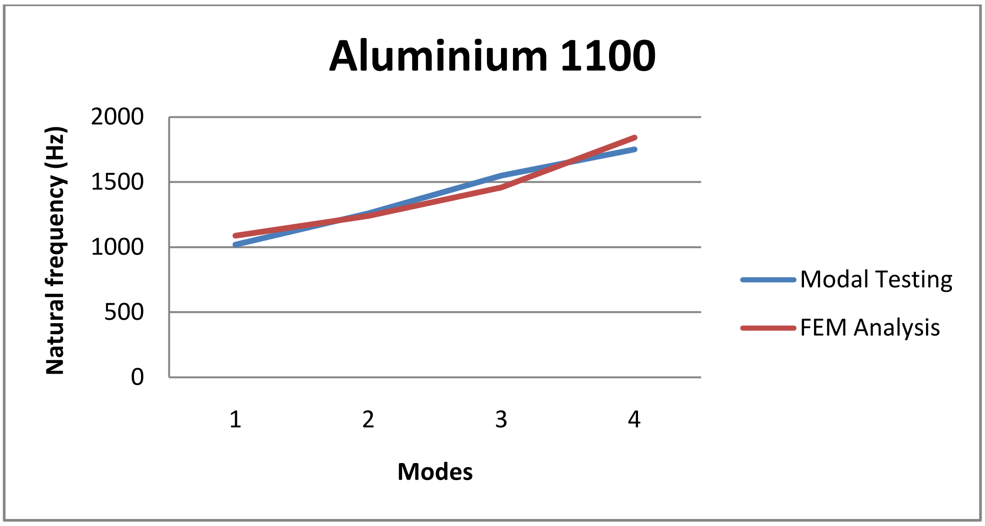


Figure 4.1: Aluminium 1100 plate analysis

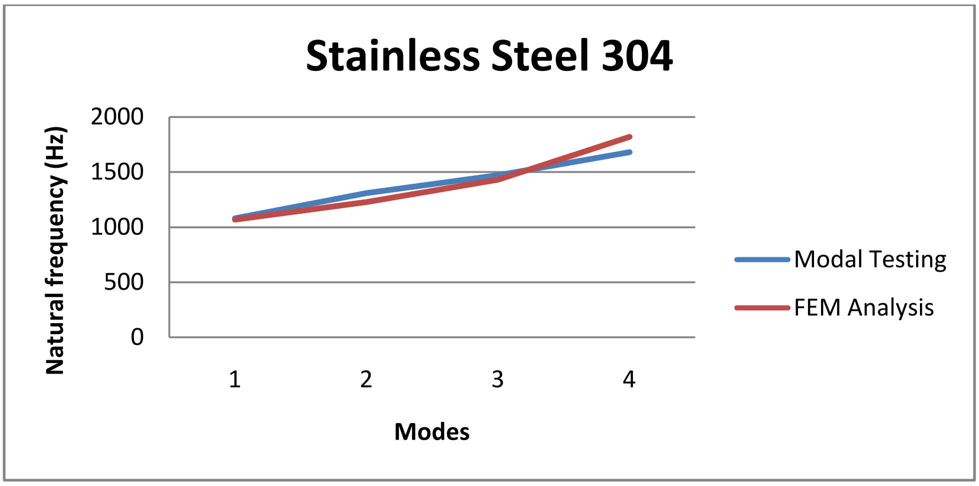
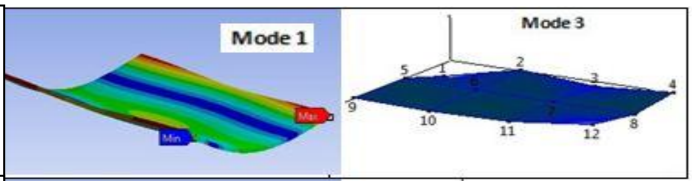


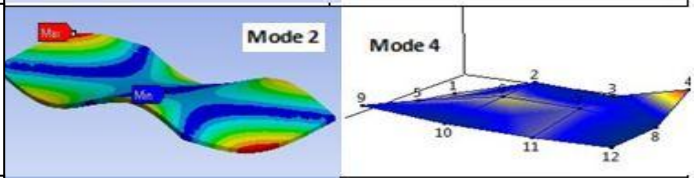
Figure 4.2: Stainless Steel plate 304 analysis

From the table 4.9 and figure 4.1, it shows that there was small error from the result that was obtained from Modal Testing and FEM software for the aluminium plate 1100. The error between the two analysis for the first to fourth natural frequency were 6.78%, 1.50 %, 5.79 % and 5.27 % respectively. While for the stainless steel 304, the first to fourth natural frequency was 1.16 %, 6.36 %, 2.71 % and 8.26 % respectively. The result that was obtained from the two analysis are different because FEA software produces an accurate result in a perfect condition while modal analysis produce results based on actual condition. As an example if the dimension was set to 100mm x 150mm for the FEA software, it will produce the same dimension without any tolerance. In actual, although the dimension is roughly 100mm x 150mm but actually the dimension has tolerance ± 1mm that can happen when the metal was cut by the shearing machine. The result that have obtained were acceptable because the error between the two analysis is less than 10%.

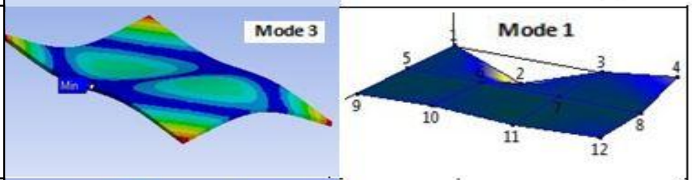
1st Bending



2nd Bending



3rd Bending



4th Bending

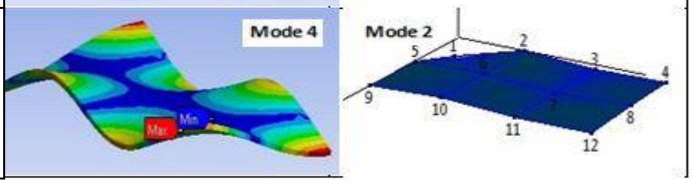


Figure 4.3: Aluminium 1100 mode shapes

Figure 4.3 shows the mode shape of aluminum 1100 from the first to the fourth natural frequency. The left side shows the mode shape from FEA (ANSYS) and the right side show the mode shape from the EMA (ME'Scope). Generally it shows that the mode shape that was produced by the ME'Scope software is different from the mode shape that was obtained from ANSYS software. The first bending mode shape for mode 1 FEA is almost similar with mode 3 for the EMA. While the second bending mode shape for the mode 2 FEA is almost similar with mode 4 from the EMA. The third bending mode shape for mode 3 of FEA is similar with mode 2 from the FEA. Lastly the fourth bending mode shape for mode 4 of FEA is similar with mode 2 form the EMA.

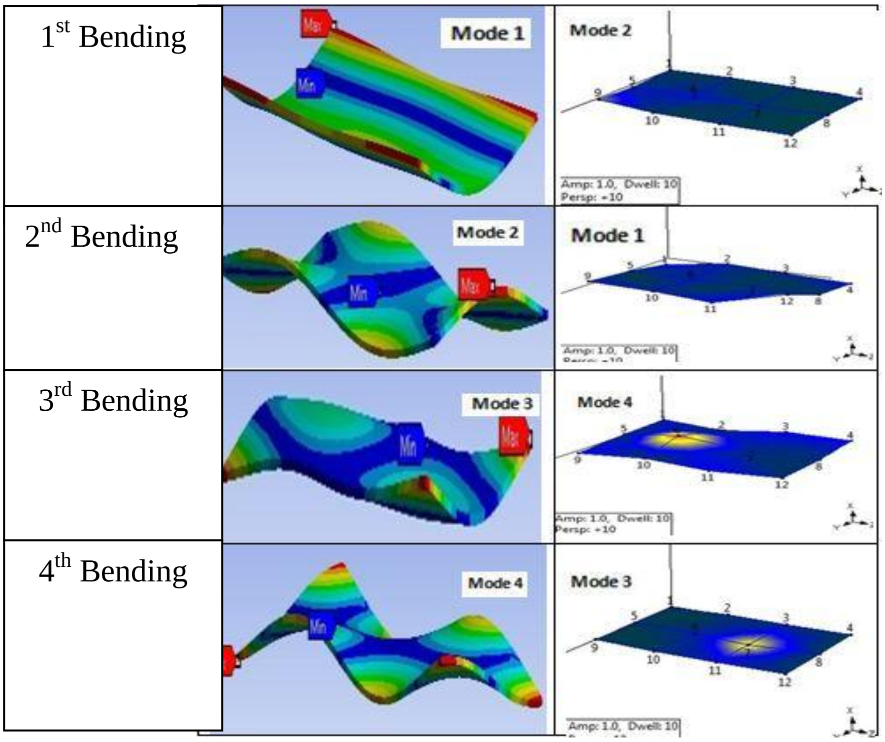


Figure 4.4 : Stainless Steel 304 mode shapes

Figure 4.4 shows the mode shape of Stainless Steel 304 from the first to the fourth natural frequency. The figure above shows that the mode shape that was produced by the ME'Scope software is different from the mode shape that was obtained from ANSYS software. The first bending mode shape for mode 1 of the FEA was almost similar with mode 2 from the EMA while the second bending mode shape of mode 2 FEA was almost similar with mode 1 from the EMA. The third bending mode shape was mode 3 from the FEA and mode 2 for the EMA while for the fourth bending mode was mode 4 for FEA and mode 3 for EMA.

4.4.2 Metal Inert Gas welding

Table 4.11 and 4.12 show the analysis result from the finite element software and modal testing of the plates that were welded by MIG machine and TIG machine. The figure 4.3 shows the graphs plotted to compare the result between the two analyses.

Table 4.11: Join using MIG welding

Modes	Modal testing (Hz)	FEA analysis (Hz)	Error (%)
1	387	330.36	14.64
2	567	439.31	22.52
3	645	617.40	4.28
4	779	736.66	5.44

Table 4.3 shows the comparison result between FEA and EMA of MIG welding. The error between the two results of first to fourth natural frequency are 14.64 %, 22.52, 4.28% and 5.44 %. The comparison shows that the first and natural frequency produces a large error unlike the third and fourth natural frequency that produce small error. As mentioned before FEA produce a result base on perfect condition while EMA produce a result base on the real condition. Other than that, there was a limitation of the FEA analysis because it cannot determine what type of welding that was used on the structure. The FEA analysis just calculated the result as a general welding structure and so the result produces a large error compare to the EMA result.

4.4.3 Tungsten Inert Gas welding

Table 4.12: Join using TIG welding

Modes	Modal testing (Hz)	FEA analysis (Hz)	Error (%)
1	310	330.36	6.57
2	484	439.31	9.23
3	612	617.40	0.89
4	721	736.66	2.17

Table 4.4 shows the comparison result between FEA and EMA of TIG welding. The error between the two results of first to fourth natural frequency are 6.57 %, 9.23 %, 0.89 % and 2.17 %. The comparison showed that natural frequency produce a small error compared to the result that was obtained from MIG welding. Although the error between EMA and FEA for the TIG welding is less than 10% the result might not be an accurate base for the reason that was stated for the MIG welding. This is because FEA software cannot determine the welding that was done to the structure and just analysed it as a welding. The result that was obtained above was still acceptable because that is the limitation of the FEA software for the moment.

4.4.4 MIG and TIG welding

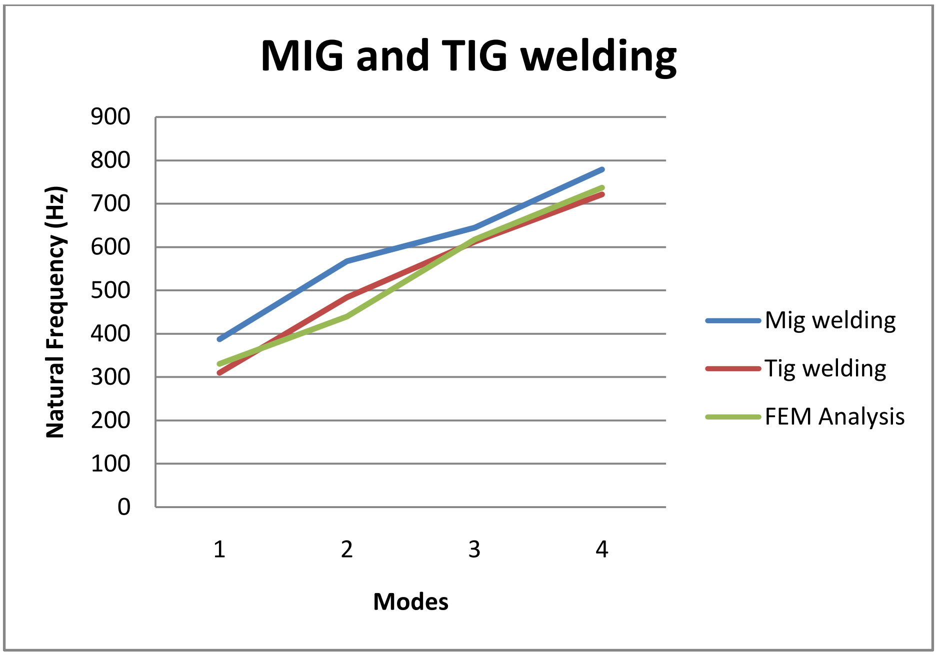


Figure 4.5: Comparison between MIG and TIG welding

The figure 4.5 shows the comparison result between EMA and FEA for MIG and TIG welding. From the graph it shows that MIG welding produces a structure that have a higher natural frequency compared to the TIG welding. The difference of the natural frequency between MIG and TIG happen due to the difference of the welding parameter. This is because the welding parameter such as current and voltage influenced the heat supply for the welding process. The heat input to the welding process will influence the material properties of the structure and thus affecting its natural frequency. This graph also shows that the EMA result from the TIG welding almost similar with the result from FEA result.

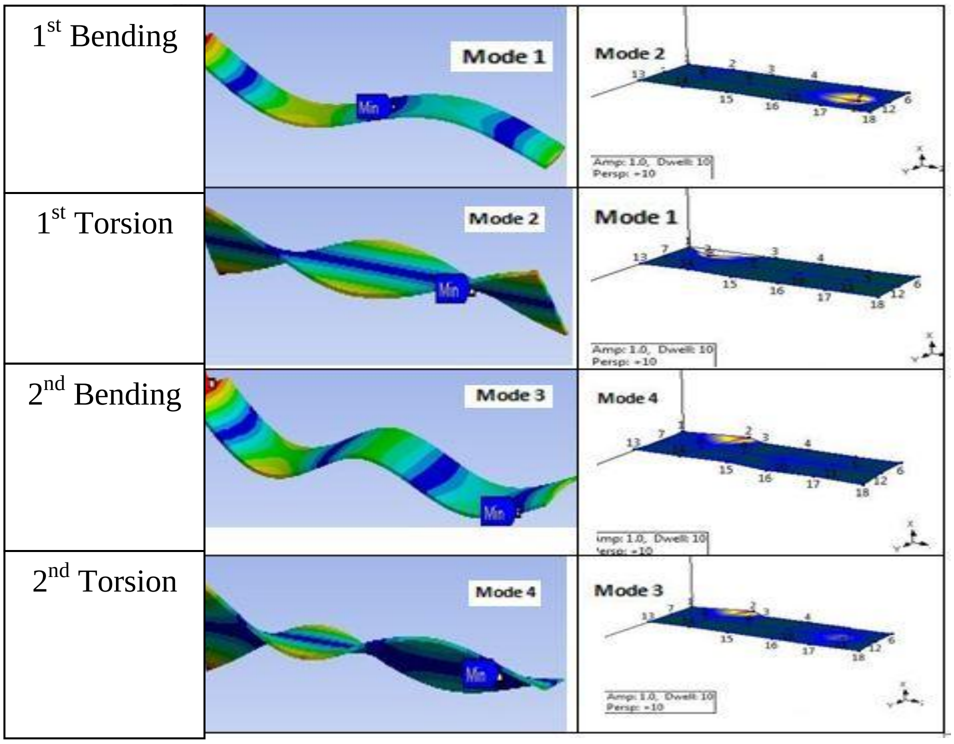


Figure 4.6 : MIG welding mode shapes

Figure 4.6 above shows the mode shape of the structure that have been welded by MIG welding. The mode shape on the left side was obtained from the FEA (ANSYS) while the mode shape on the right side was obtained from the EMA (ME'Scope). The mode shape for first and third natural frequency for the FEA show a bending structure while the second and fourth natural frequency shows a torsion structure. The first bending mode shape was mode 1 from the FEA and mode 2 from the EMA while the second bending mode shape was mode 3 form the FEA and mode 4 from the EMA. The first torsion mode shape happen at mode 2 for the FEA and mode 1 for the EMA while the second torsion mode shape happen at mode 4 for the FEA and mode 3 for the EMA.

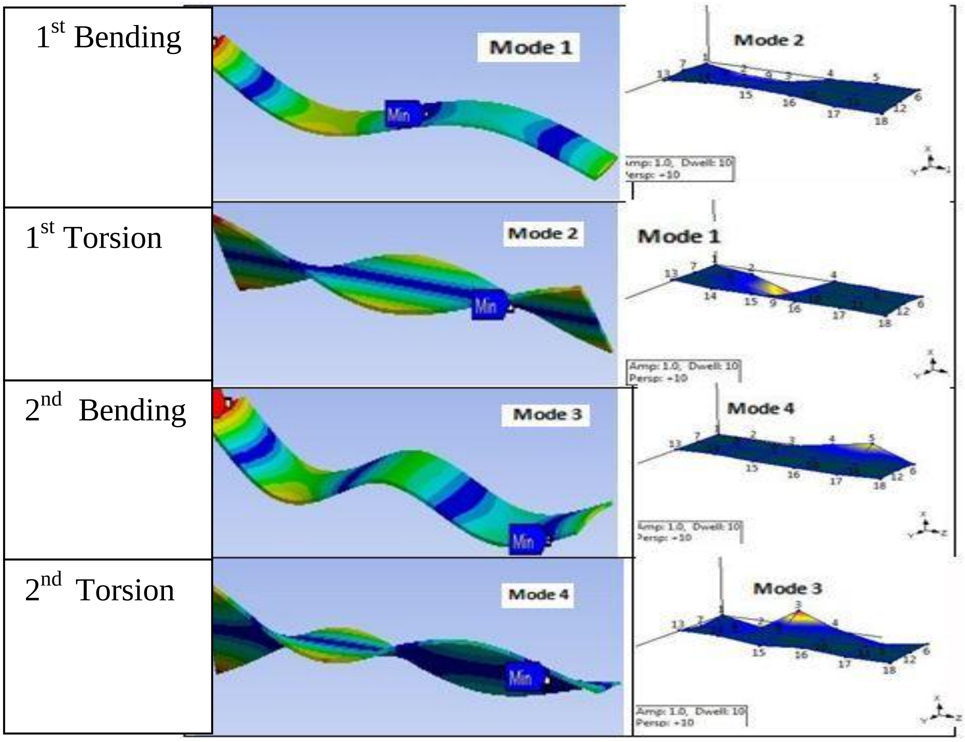


Figure 4.7 : TIG welding mode shapes

Figure 4.7 above shows the mode shape of the structure that have been welded by TIG welding. The mode shape on the left side was obtained from the FEA (ANSYS) while the mode shape on the right side was obtained from the EMA (ME'ScopeE). The mode shape that was obtained from the FEA was same with the MIG welding because of the limitation of the current ANSYS. This problem happened because above the ANSYS software can not determine the welding type that was done to the structure thus producing results that might not same with the real condition. The first bending mode shape happened at mode 1 for the FEA analysis and occur at mode 2 for the EMA while the second bending mode shape occur at mode 3 for the FEA and mode 4 from the EMA. The first torsion mode shape occur at mode 2 for the FEA and mode 1 for the EMA while the second torsion mode shape happen at mode 4 for the FEA and mode 3 for the EMA.

4.5 ORDINARY DEFLECTION SHAPE RESULT

This section shows the result that was obtained from the ODS and the result that was calculated from the formula. The mode shape that obtained from MESCOPE software were compared to the mode shape that was plotted based on the result of the calculation.

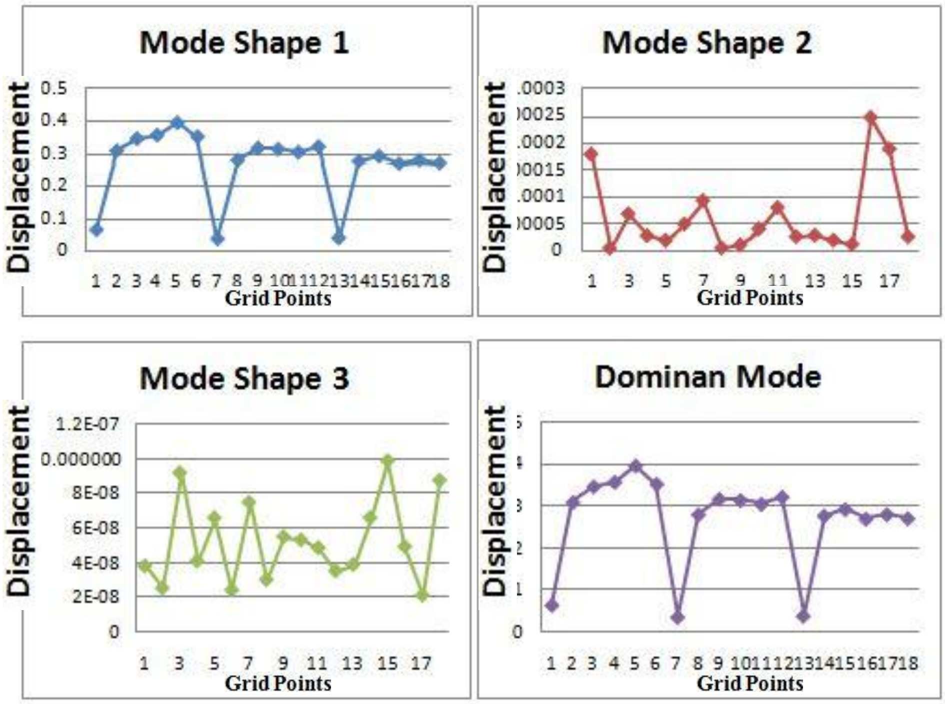


Figure 4.8: Mode shape for the MIG weld

The result was calculated from the formula and the graph in the figure was plotted using Microsoft Excel. From the graph the dominant mode of the structure can be determined when operating at 53.3 Hz. The dominant mode was calculated by adding the value of the response.

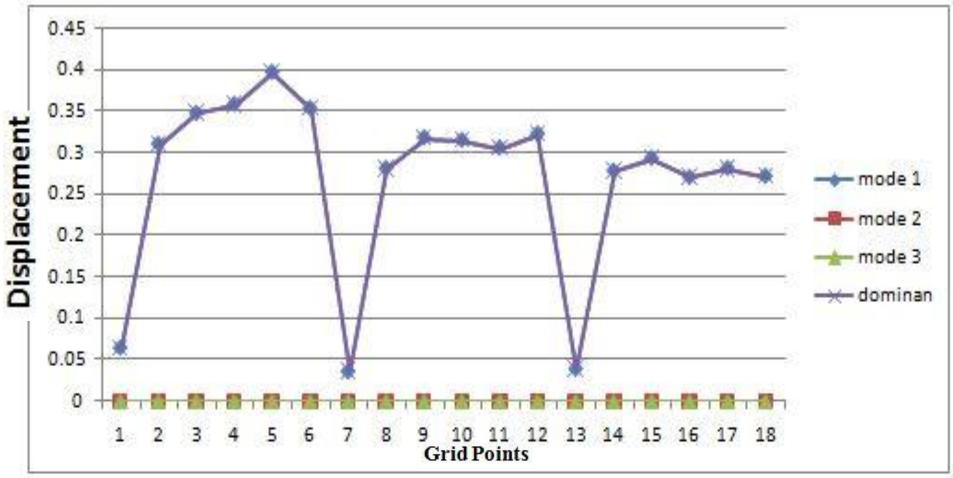


Figure 4.9: Dominan mode shape for MIG weld

Figure 4.9 above shows the dominant mode shape of the structure. From the graph plotted the mode that was more dominant when operating under 53.3 Hz is mode 1. The mode shape was then compared with the mode shape that was obtained from the ME'Scope software to validate the result of the calculation.

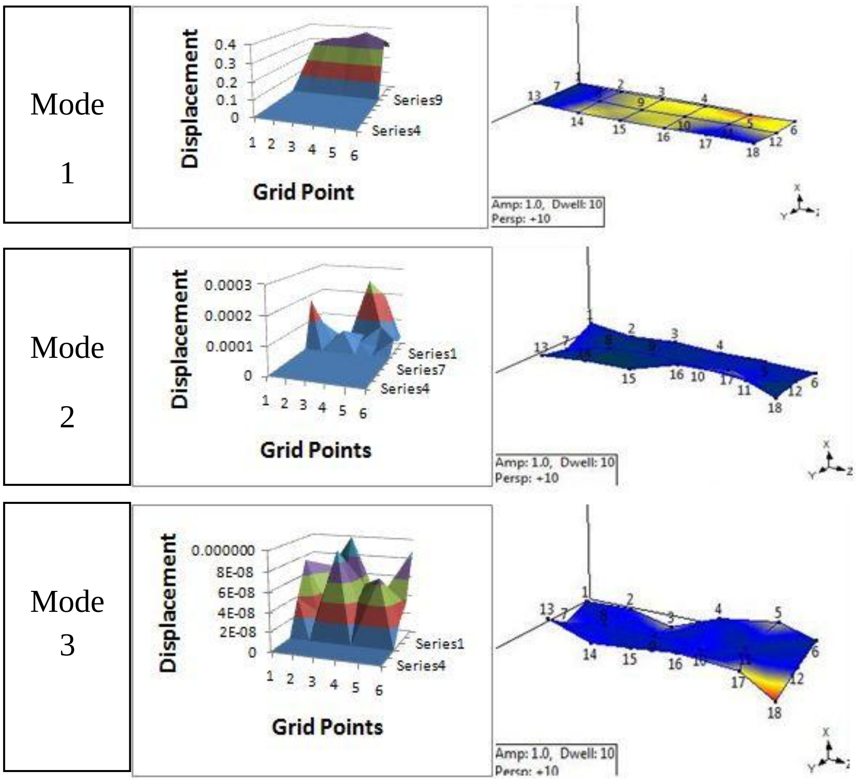


Figure 4.10: The mode shapes of the MIG welds using ODS

Figure 4.10 shows the mode shape from the calculation and from the ME'Scope software. The right side shows the mode that was plotted using ME'Scope software and the left side show the mode shape that was plotted using Excel. The mode that was determine as the dominant mode when operating under 53.3 Hz is mode 1.

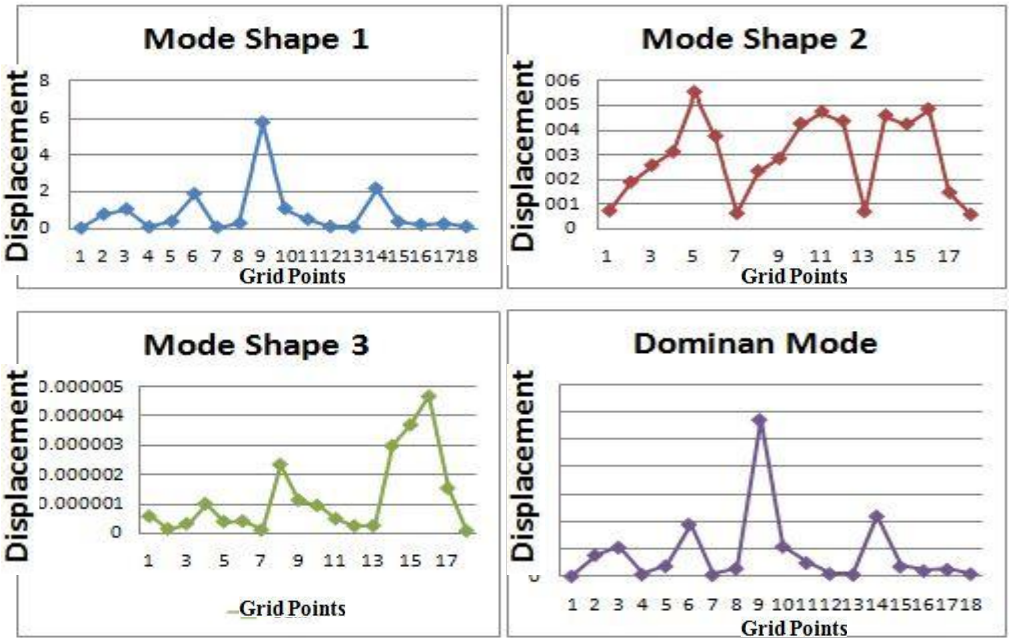


Figure 4.11: Mode shape for the TIG weld

The result above was calculated from the formula and the graph in the figure was plotted using Microsoft Excel. From the graph the dominant mode of the structure can be determined when operating at 53.3 Hz. The dominant mode was calculated by adding the value of the response.

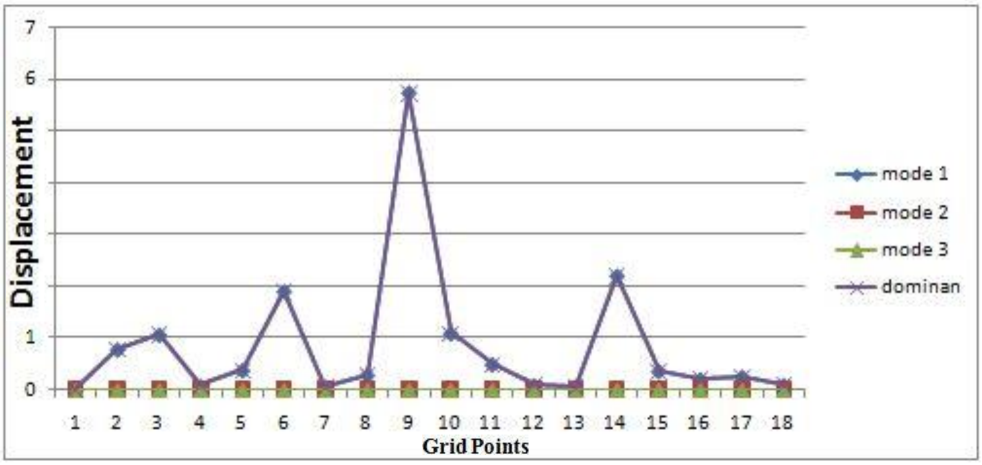


Figure 4.12: Dominant mode shape for TIG weld

Figure 4.12 above shows the dominant mode shape of the structure. From the graph plotted the mode that was more dominant when operating under 53.3 Hz is mode 1. The mode shape was then compared with the mode shape that was obtained from the ME'Scope software to validate the result of the calculation

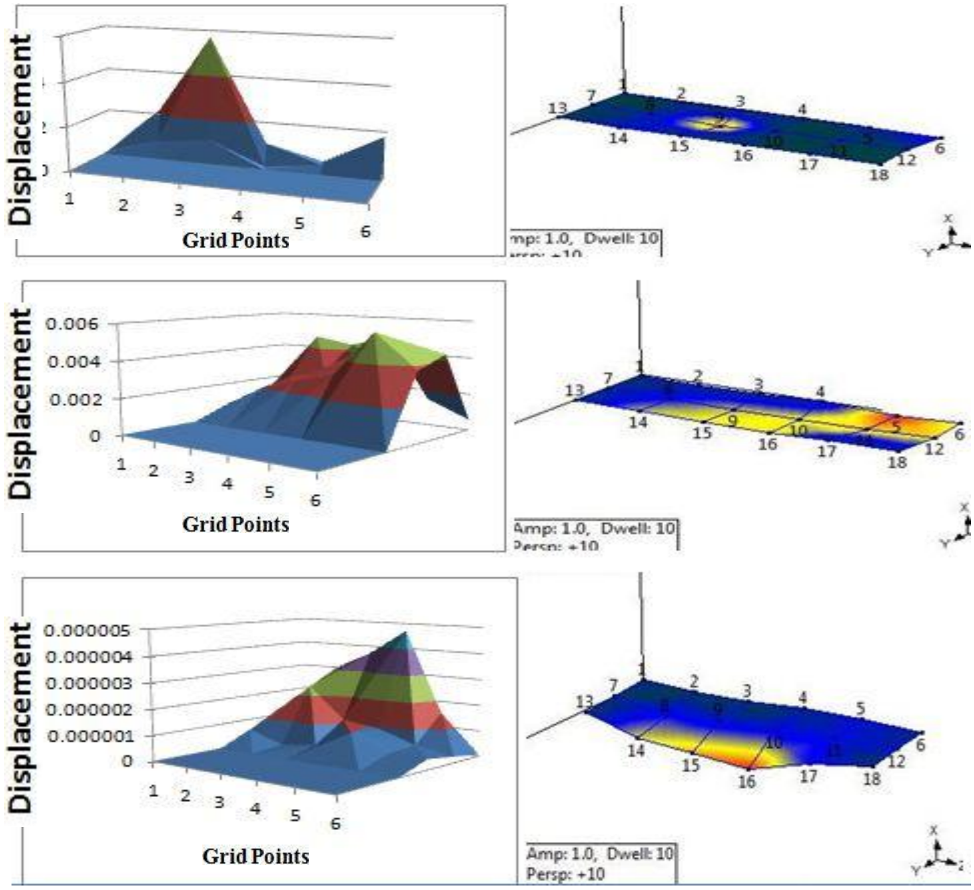


Figure 4.13: The mode shapes of the TIG welds using ODS

Figure 4.13 shows the mode shape from the calculation and from the ME'Scope software. The right side shows the mode that was plotted using ME'Scope software and the left side show the mode shape that was plotted using Excel. The mode that was determine as the dominant mode when operating under 53.3 Hz is mode 1.

The ODS was done to the structure so that the dominant mode can be determined when there is excited force operating on the structure. Both of the result show that the dominant mode when the structure operating under 53.3 Hz is mode 1.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The objective of this report is to study the effect of MIG and TIG welding using modal analysis. The effect of MIG and TIG welding can be determined by studying the dynamic characteristic of the structures. Other than that the result that was from FEA and EMA was studied and investigate either producing a consistent result. This study has proven that the dissimilar metal (Al – Sus) was difficult to weld due to the high different of the melting point. MIG welding from this study produce a better weld bead compare to the TIG welding. This may result from inexperience of the welder for the TIG welding compare with the MIG welding that is an automated welding machine.

The main objective of this study also was achieved where there was effect of MIG and TIG weld to the structure. The MIG effect produced structures that have a higher natural frequency compared to the TIG weld structure. In the future when selecting the between MIG and TIG weld that will be done to the structure this result can be taken as a consideration. If the situation needs that have a higher natural frequency the MIG weld can be choose but if a lower natural frequency structure is needed for the structure the TIG weld can be used instead.

The result also shows that there was a good consistency natural frequency that was obtained from the modal testing and from the FEA. This study was an initial step to produce a better structure that has better properties with the concern of the dynamic characteristic of the structure.

5.2 RECOMMENDATIONS

For the future research Non Destructive Test (NDT) and destructive test should be done to the structure before it is used for the modal testing. The NDT will ensure that the weld structure has no defect while the destructive test ensure that the weld is a sound weld that have better certain properties compare with their parent metal. Die Penetrate Test is one of the examples of NDT test where the defects in the structure can be detected without have to destroy the structure.

Other than that the welding parameter also should be studied to ensure that the welding that was done to the structures is sound weld. The dissimilar welding was difficult to be done because of the parameters that are involved such as weld speed, current and voltage. The correct parameters of welding not only reduce the defect but also ensure the structure does not fail.

Post or preheat treatment also can be done to the structure because the effect of this process will affect the residual stress of the welding. After the welding was done, the stress usually concentrated in the weld area. So by pre or post heat treatment, the residual stress concentration can neutralize back. The pre or post weld heat treatment should be done because the high concentration of residual stress on the weld area may lead to fatigue and brittle fractures (Teng et al., 2003). The effect of residual stress also will be affecting the natural frequencies of the structures.

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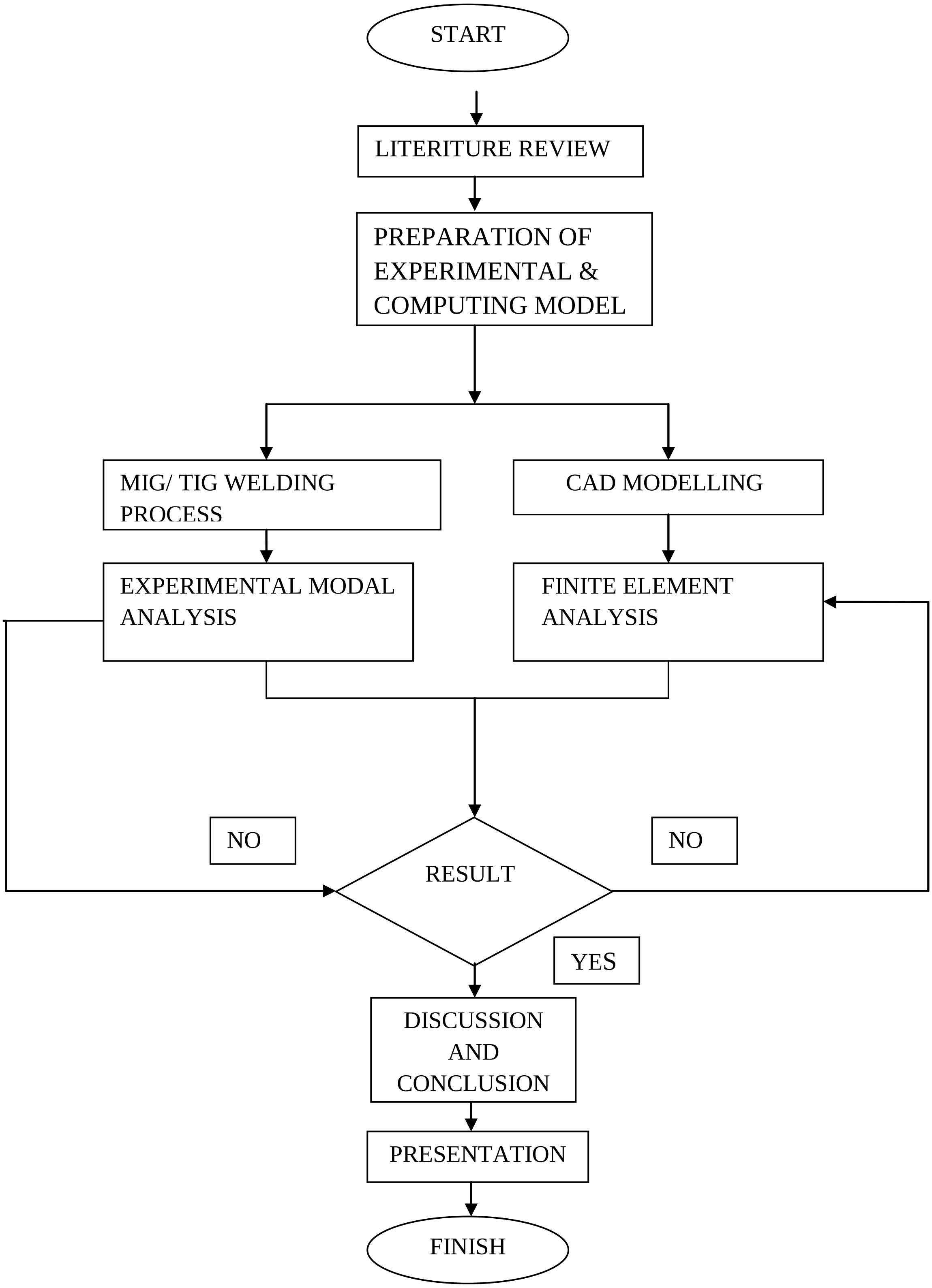
APPENDIX A

FLOW CHART



APPENDIX B

GANTT CHART FYP 1

Week / Progress	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing about title From supervisor	■													
Reading journal and article related		■	■											
Finding suitable material and joint that will be used				■										
Learn about modal testing, impact hammer test and Daisy Lab					■	■	■							
Learn using FEA software and to choose with one that will be use								■	■	■				
Learn using MIG and TIG machine to weld the structure.											■	■	■	
Writing report for FYP 1													■	■

APPENDIX C

GANTT CHART FYP 2

Week / Progress	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Conduct MIG welding to the structure.	■	■												
Conduct TIG welding to the structure			■	■										
Modal Testing to the all structure.					■	■	■							
Use FEA to analyze structure								■	■	■				
Using ODS to analyze structure.											■	■		
Result and Conclusion													■	
Presentation FYP 2														■